This report on the geomorphology of the Lakeshore area continues the series of Pictured Rocks Resource Reports. It summarizes Dr. Blewett's efforts over three field research seasons studying and interpreting the landforms in the Lakeshore area. Reader comments on the Reports are invited.

Grant A. Petersen
Superintendent

Pictured Rocks RESOURCE Report

PIRO 94-01

LATE WISCONSIN HISTORY OF PICTURED ROCKS NATIONAL LAKESHORE AND VICINITY

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INTRODUCTION

The deglaciation history of Pictured Rocks National Lakeshore (PRNL) is generally well understood (Hughes, 1968; Drexler and others, 1983; Blewett and Rieck, 1987), but much relevant literature is unpublished and no comprehensive study of Late Wisconsin events exists.

Accordingly, this report is designed to synthesize all published and available unpublished information on the park's glacial geomorphology. It also provides a detailed deglaciation history based on an analysis of large-scale topographic quadrangles, some newly available, and addresses several unresolved aspects of final deglaciation.

SEDIMENT AND LANDFORM CHARACTERISTICS

Sediments - Precambrian and Paleozoic sedimentary rocks, described by Hamblin (1958) and Haddox and Dott (1990), underlie drift of variable thickness within PRNL. The Jacobsville Formation, a red sandstone of Precambrian age, is the oldest rock exposed in the park. The Late Cambrian Munising Formation lies unconformably above the Jacobsville and consists of three members: a basal conglomerate, the Chapel Rock Sandstone, and the Miners Castle Sandstone. Capping the Munising Formation is the resistant Au Train Formation of Early Ordovician age. This light brown to white dolomitic sandstone is the most widespread sub-cropping lithology in areas of thick drift south and east of the park. Overall, each of the Paleozoic formations dips gently south toward the center of the Michigan structural basin.

A recently compiled but unpublished map of Alger County bedrock topography was generously provided by R.L. Rieck (1991) for use in this report. Based on hundreds of well logs, this map furnishes the most detailed bedrock information now available, and provides a basis for regionalizing its surface and for determining drift thickness.

Inland between Munising and Grand Portal Point, a thinly mantled low-relief bedrock plateau at approximately 260-275 m above sea level drops steeply lakeward to 100 m at Sand Point. Farther east, the plateau is interrupted by the 60 m deep, north-south trending Miners bedrock valley. A buried bedrock valley of similar size and trend may also exist near Kingston Lake (Blewett and Rieck, 1987). Near the park's eastern boundary, bedrock altitudes drop from 267 m four kilometers south of Grand Marais to less than 150 m at the lakeshore.

Drift thickness increases from west to east in PRNL. South and west of Grand Portal Point, drift is absent or very thin within several kilometers of the shoreline, becoming thicker inland, but seldom exceeding 10 m. Drift thickens eastward, reaching at least 25 m along the lakeshore 2.5 km southwest of Twelvemile Beach Campground (NW 1/4, sec. 19, T49N, R15W), more than 30 m southeast of the campground (SE 1/4, sec. 17, T49N, R15W), 20 m near the mouth of Sullivan Creek (SE 1/4, sec. 9, T49N, R15W) and 25 m along Hurricane River (NW 1/4, sec. 23, T49N, R15W).

Farther inland, drift thickness likely exceeds 20 m (Blewett and Rieck, 1987). South of Grand Marais, however, a broad bedrock headland is thinly mantled by drift and in places bedrock crops out.

Surficial sediment characteristics differ markedly between eastern and western sections of PRNL. Sandy till prevails inland south and west of Grand Portal Point (Hughes, 1968), whereas outwash predominates to the east, with very limited amounts of flow till, melt-out till, and glaciolacustrine sediment.

Glaciofluvial deposits are exposed at a gravel pit in the SW 1/4, sec. 21, T48N, R16W, where rounded boulders up to 60 cm in diameter exist within a matrix of sand and coarse gravels. Slumped faces prohibit identification of diagnostic bedforms, but crude horizontal bedding is present. Areas mapped as coarse-textured till southeast of Kingston Lake (Farrand

and Bell, 1982) are almost certainly ice-contact and proglacial stratified drift.

Landforms - The Munising moraine (Leverett, 1929), a conspicuous east-west trending highland, skirts the southern edge of PRNL. Blewett and Rieck (1987) proposed that parts of this feature are better interpreted as complex ice-wastage landforms consisting of stratified drift. Such features are especially well developed northeast of Melstrand, where a 3 km long, 15 m high esker grades into a large outwash fan (secs. 3 and 11, T47N, R17W). Hughes (1968) noted that extensive tracts between Melstrand and Munising previously mapped as moraine are actually till plain, containing northwest-southeast oriented flutes and drumlins.

The northern flank of the Munising moraine exhibits a complicated assemblage of kame terraces and incised channels formed by eastward-flowing meltwater streams that were confined between the glacier's margin and ice-free highlands to the south (Figs. 1, 2). West of Beaver Lake, many channels were carved into bedrock, as at Chapel Lake gorge, but eastward the landforms are mainly constructional, including collapsed heads of outwash containing thick drift (SE 1/4 SE 1/4, sec. 11, T49N, R15W, for example). Lakeward, some of these features are truncated by a well developed beach scarp at approximately 195 m formed by an ancient, higher-level ancestor of Lake Superior, Lake Nipissing.

PREVIOUS WORK

Frank Leverett (1911, 1917, 1929) mapped and interpreted the surficial geology of Michigan's Northern Peninsula, identifying the yet unnamed Munising feature as a moraine "deposited in water or later covered by waters of glacial lakes," and the flanking terraces west of Grand Marais as "sandy beds of glacial lakes (1929)." This mapping reflected the mistaken belief that after formation, most of the moraine was submerged beneath Lake Algonquin, an ancestral high-level lake that occupied the basins of Lakes Huron, Michigan, and Superior following final deglaciation. Farrell and Hughes state (1985, p. 75):

"Working without the benefit of aerial photographs and topographic maps, Leverett misinterpreted many glacial features such as ice contact slopes and outwash channel banks as ancient shorelines. This led him to postulate that the high level Algonquin stage occupied not only the basins of lakes Huron and Michigan, but also the entire basin of Lake Superior."

Bergquist (1936a), following Leverett, described the moraine in detail, recognizing its ice-contact character. In a separate report, he (1936b) proposed that the Grand Sable Banks formed as a baymouth bar in Lake Algonquin, with Grand Sable Lake marking a remnant lagoon enclosed by the bar. Martin (1957) mapped the Northern Peninsula's surficial formations, closely following Leverett and Bergquist.

Hough (1958), however, proposed that Lake Algonquin was restricted from most of the Lake Superior basin, and that outwash aprons of the Munising moraine were graded to lake levels that formed in the Michigan and Huron basins after the

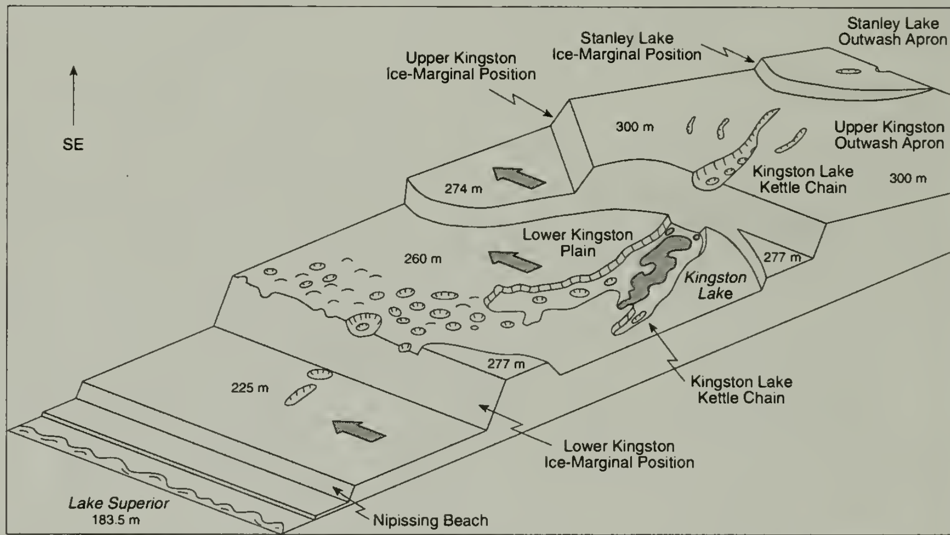


Figure 1. Landforms in the vicinity of Kingston Lake. Arrows show direction of meltwater drainage.

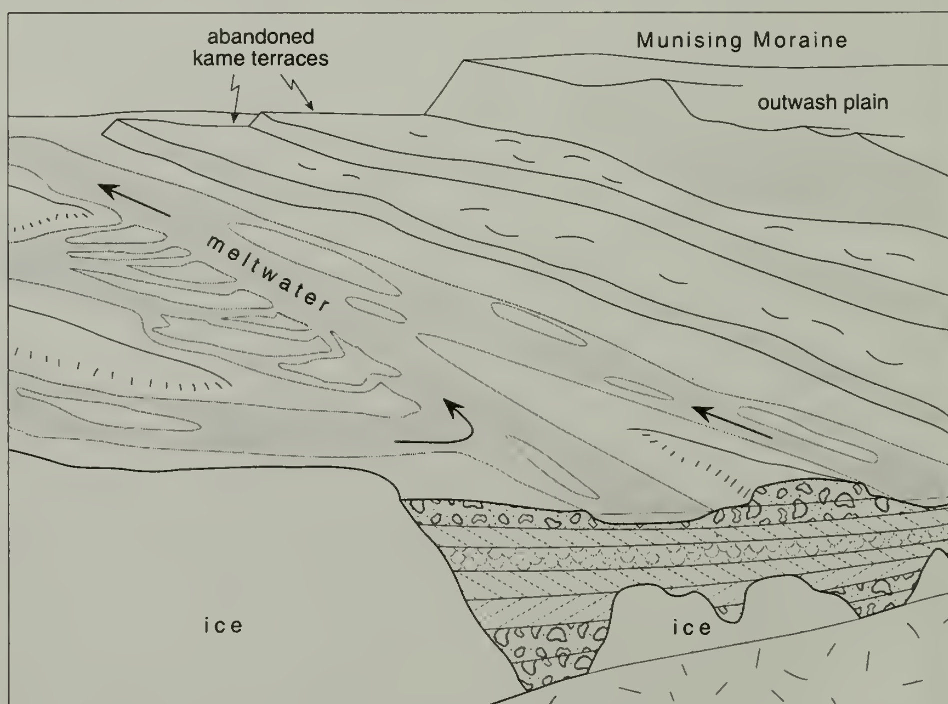


Figure 2. Formation of kame terraces. From a drawing by Gregg Bruff.

Main Lake Algonquin phase had ended (Algonquin "upper group" lakes).

John Hughes began research in the area in 1958 and was possibly the first to recognize the glaciofluvial origin of terraces and incised channels north of the moraine (Farrell and Hughes, 1985). He later confirmed their eastward slope and proposed a generalized deglaciation history that was incorporated into the PRNL Master Plan (Hughes, 1968). Later, Drexler (1975) presented a deglaciation history similar to Hughes in most respects.

By 1975 geologists had developed a complex Great Lakes deglaciation chronology based in large part on radiocarbon dating. They concluded that beginning about 11,500 before present (B.P.), the ice margin rapidly retreated northward from a terminal position near Two Rivers, Wisconsin. This recession was punctuated by two major still stands of the ice as represented first by the Newberry moraine, an east-west trending highland paralleling the Northern Peninsula's southern shore, and then the Munising feature.

Although no age estimates from the Munising moraine were available, most researchers considered it to be approximately 11,000 years old based on its assumed relationship to the complicated sequence of Algonquin lake phases. Karrow and others (1975) concluded that the Main Lake Algonquin level was established after 11,200 yr. B.P. and had drained to lower levels by 10,600 yr. B.P. If outwash aprons of the Munising moraine were graded to Post Algonquin "upper group" levels as suggested by Hough (1958), then the age of the Munising feature was bracketed by these dates, or only slightly younger. Futyma (1981) contended that Munising outwash was actually graded to the higher Main Algonquin level, placing the feature squarely between Karrow's age estimates.

Excavations at Gribben Lake near Marquette, Michigan, uncovered spruce stumps buried by outwash of the Marquette moraine (Hughes, 1978), a correlative of the Munising moraine (Hughes, 1971). Five dates from wood samples provided a mean age of 9,925 yr. B.P. Based on these age estimates, Hughes named the ice-free interval of forest growth the Gribben Interstadial, and the subsequent period of ice readvance the Marquette Stadial.

Because the Marquette moraine was now firmly dated at approximately 10,000 B.P., the correlative Munising moraine (and associated landforms) was assumed to be the same age, or 1,000 years younger than previously thought. Hughes was unable to determine how far the ice margin had retreated into the Superior basin during the Gribben Interstadial before readvancing, but researchers studying Lake Agassiz farther west would soon answer this question.

Contemporaneous with formation of these moraines, a vast glacial lake (Lake Agassiz) covered parts of Saskatchewan, Manitoba, Ontario, Minnesota, North Dakota, and South Dakota. Detailed work on its shorelines, deposits, and outlet channels by various workers (Clayton, 1983; Teller and Thorleifson, 1983) indicated that Lake Agassiz drained into the Lake Superior basin during two distinct episodes: the Moorehead (10,800-9,900 B.P.) and Nipigon phases (9,500-8,500 B.P.) (Teller and Thorleifson, 1983). The location of Lake Agassiz outlets required that the Lake Nipigon area, and by analogy most of the Superior basin, be ice free during episodes of Lake Agassiz overflow.

Because the Moorehead phase coincided with Hughes' Gribben Interstadial, researchers concluded that the ice margin withdrew to the northern edge of the Superior basin between 10,800 and 9,900 B.P., allowing overflow from Lake Agassiz (Moorehead phase) to enter the then mainly ice-free Superior basin. Ice then readvanced southward during the Marquette Stadial, blocking Lake Agassiz outlets and building the Munising-Marquette moraines c. 10,000 yr. B.P. Eventual ice-marginal retreat reopened the Lake Superior basin about 9,500 B.P., allowing overflow from Lake Agassiz (Nipigon phase) to reenter the basin.

Drexler (1981) documented the sequence of lakes and drainageways associated with ice withdrawal following the Marquette Stadial. At this time, proglacial lakes occupied the eastern and western sections of the Superior basin, with western lakes draining southward to the Michigan basin (Fig. 3). Ice-marginal retreat in the vicinity of PRNL allowed meltwater from these western lakes to flow eastward, forming some of the terraces and incised channels within PRNL (Fig. 4).

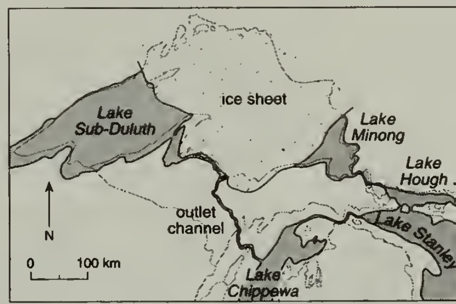


Figure 3. Glacial lakes in the Superior basin at the time of the Marquette advance. From Drexler, 1981; p. 267.

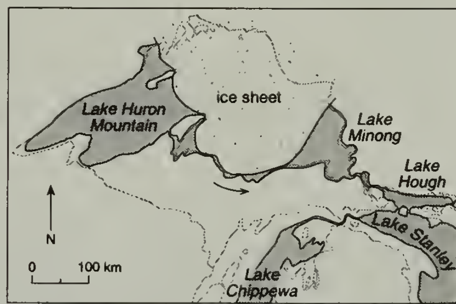


Figure 4. Glacial lakes in the Superior basin at about the time of the cutting of the Chapel Lake gorge. From Drexler, 1981; p. 281.

These relationships mean that the Munising moraine's revised age is incompatible with Hough (1958) and Futyma's (1981) earlier proposals that the feature's drainage was graded to Algonquin water levels. Specifically, a moraine 10,000 years old could not be graded to a lake that had drained 600 years earlier.

Drexler and others (1983) further complicated the issue by proposing that the Munising moraine did not represent a significant stillstand of the ice margin, but was instead simply higher bedrock mantled with thin drift. In its place, a new feature, the Grand Marais moraine, was delineated and interpreted as having formed during the Marquette Stadial readvance. Drexler's Grand Marais moraine was thus somewhat younger than his discredited Munising moraine, which was interpreted to be a result of higher bedrock, not ice-marginal deposition. Drexler (Farrand and Drexler, 1985) reiterated these interpretations in a later paper.

Figure 5-1

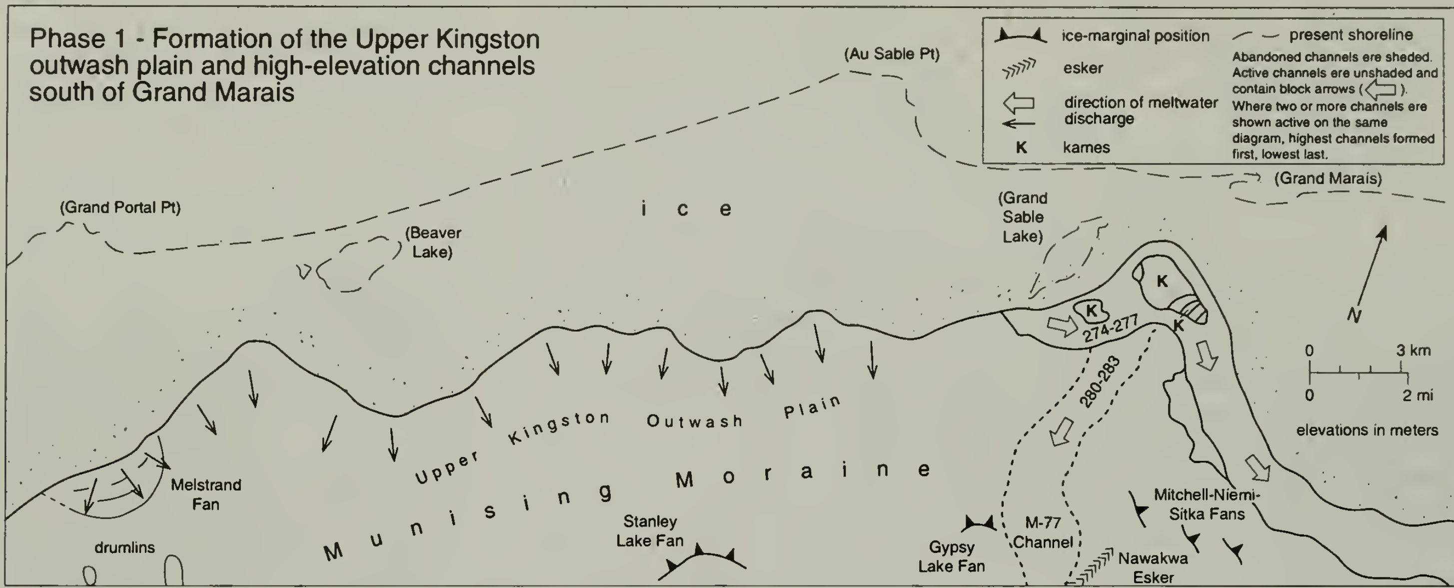


Figure 5-2

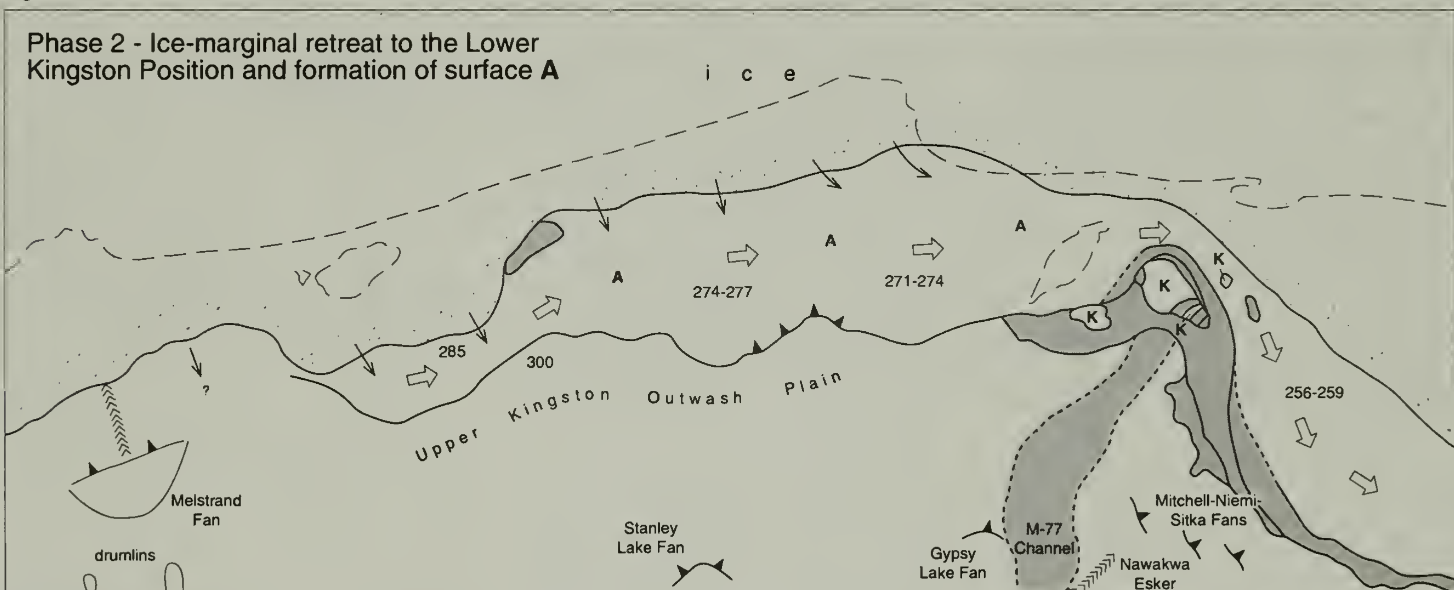
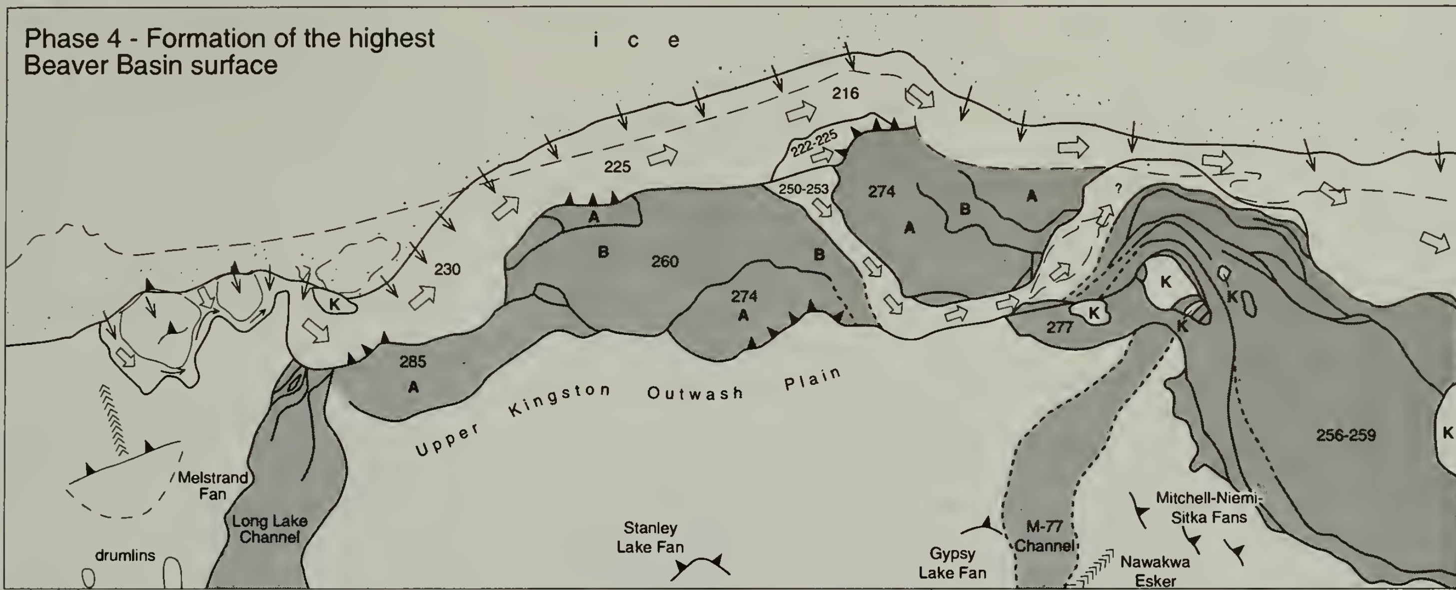


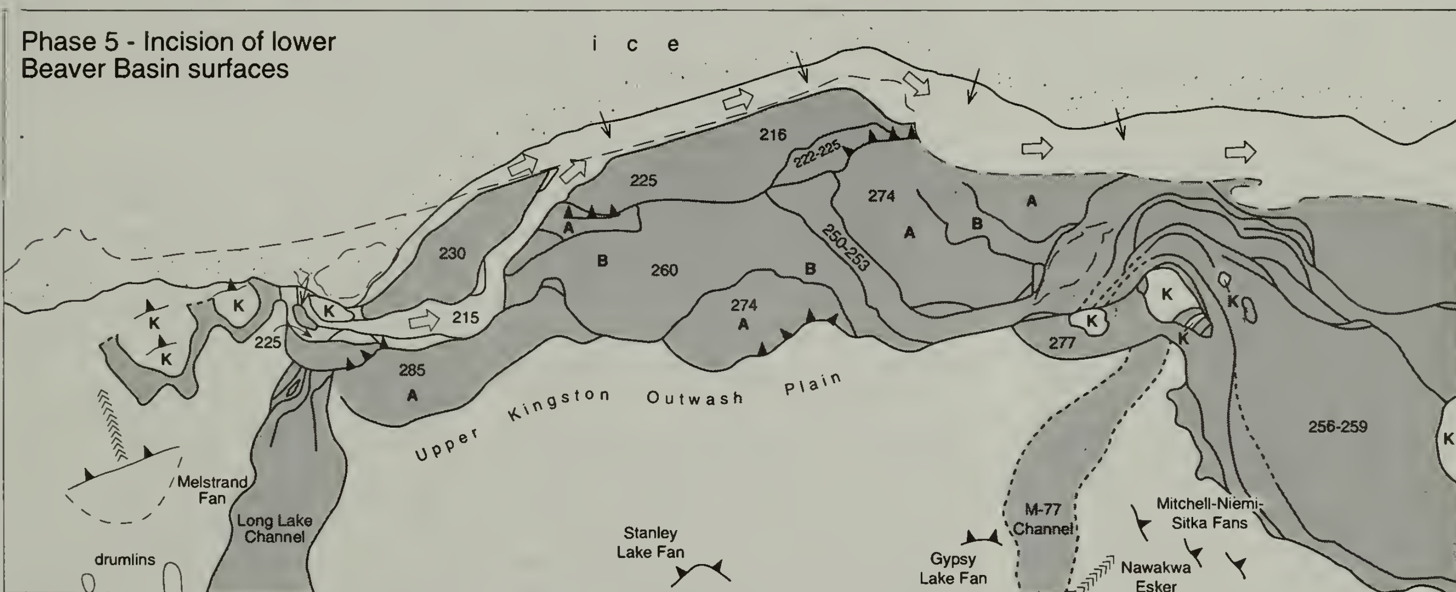
Figure 5-3

Figure 5-4



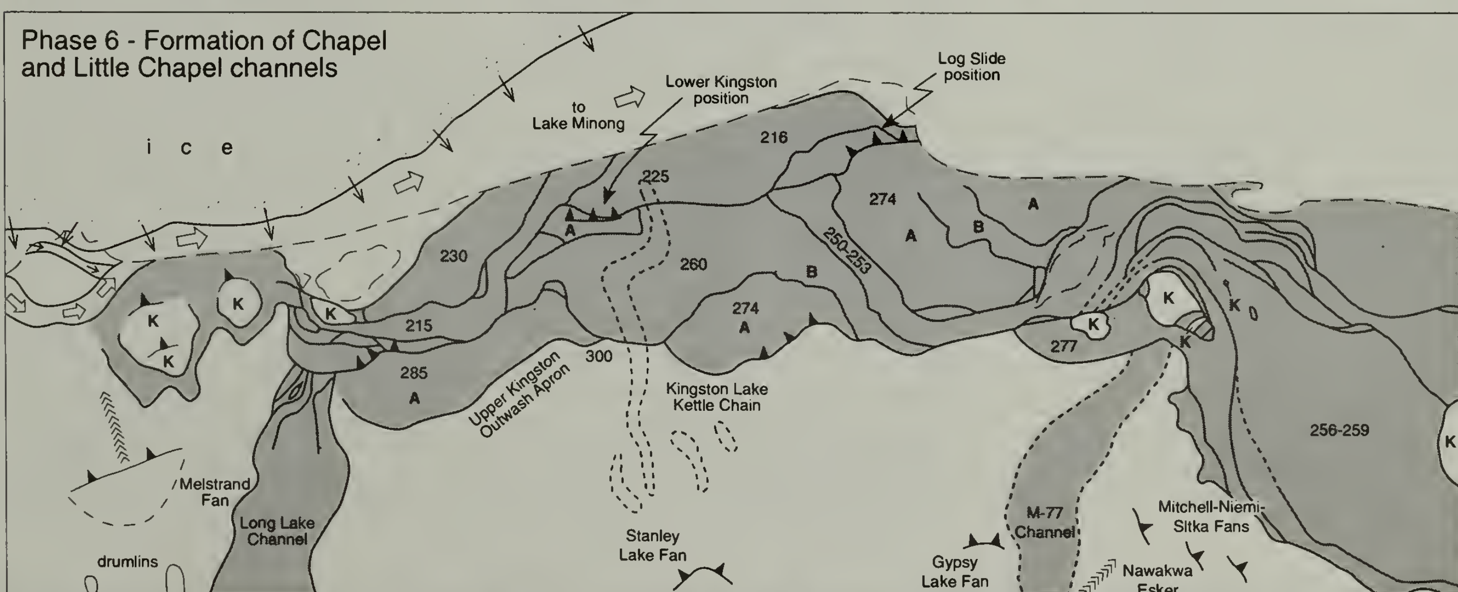
Phase 4 - Formation of the highest Beaver Basin surface

Figure 5-5



Phase 5 - Incision of lower Beaver Basin surfaces

Figure 5-6



Phase 6 - Formation of Chapel and Little Chapel channels

Blewett and Rieck (1987) questioned Drexler's conclusions and, based on topographic and subsurface data, showed that mean drift thickness in sections of the Munising moraine averaged 15 m and likely exceeded 20 m. In addition, they proposed that large parts of the moraine were complex ice-wastage features containing stratified drift that delimited three successive ice-marginal positions.

As of this writing, the weight of evidence suggests that terraces and incised channels north of the moraine within PRNL are likely associated with ice-marginal retreat following the Marquette Stadial, making most glacial landforms within the park approximately 9,900 years old or perhaps slightly younger. Differentiation of the Grand Marais and Munising moraines (if two separate landforms do exist) remains unclear, as does the significance of outwash aprons apparently graded to Algonquin water levels.

DEGLACIATION HISTORY

The six-phase deglaciation history proposed here is based on detailed analysis of 1:24,000 and 1:25,000 topographic quadrangles, some newly available, as well as field work completed in June, 1994. It builds upon scenarios proposed by Hughes (1968) and Drexler (1975) by identifying several previously undocumented heads of outwash and ancillary terraces. Because the terminal position of Marquette ice cannot be determined with certainty, the glacial history begins with the first Late Wisconsin ice-marginal positions to have influenced topography within PRNL.

Phase 1

Sometime after 10,000 B.P. the ice margin likely stood along the Melstrand fan and Upper Kingston outwash plain (Fig. 5-1). Supporting evidence includes boulder concentrations along apron crests south of Beaver Lake (SE 1/4, sec. 20, T48N, R16W) and at Section 35 Hill (SE 1/4, sec. 35, T49N, R15W). Meltwater flowed south from this position as indicated by southward-fining surficial deposits (Blewett and Rieck, 1987). The great size and extent of these features suggests formation during an equilibrium period of significant duration, perhaps lasting several decades.

As ice withdrew from this position, meltwater dammed between the glacier border and the adjacent highlands spilled southward, forming a wide channel at 283 m that today parallels highway M-77 (M-77 channel, Fig. 5-1). Continued retreat opened a lower channel at 274-277 m (Fig. 5-1). Several higher ancillary surfaces are located in the N 1/2 sec. 19, T49N, R13W.

Phase 2

Ice-marginal retreat to a new position along the Lower Kingston plain (Hughes, 1968) opened lower eastern drainage outlets. Meltwater, confined between the terminus and the now abandoned Upper Kingston ice-contact slope, formed a broad, eastward-sloping kame terrace heading at approximately 285 m (surface A; Fig. 5-2). Crestal boulders indicative of ice-marginal positions exist northwest of Kingston Lake (NE 1/4, sec. 36, T49N, R16W) and west of the Log Slide (SE 1/4, sec. 11, T49N, R15W).

Phase 3

While the glacier's border remained at the Lower Kingston position, marginal retreat from the highland south of Grand Marais opened a still lower outlet, permitting meltwater streams to incise a new channel (surface B) into surface A (Fig. 5-3). Further recession allowed incision of a lower, 250-253 m channel that today contains the Hurricane River (Fig. 5-4). These latter surfaces likely record the transition to non-equilibrium conditions just prior to abandonment of the Lower Kingston position.

Meanwhile, meltwater trapped between the ice margin and the Lower Kingston ice-contact slope south of Beaver Lake spilled southward, forming the Long Lake channel (Fig. 5-3). This feature exhibits an extensive 280 m surface, with at least two smaller incised channels at 277 m and 274 m. Gravel pits along the channel bottoms contain boulders up to 30 cm in diameter in sand and coarse gravel. The 274 m channel also formed a distinctive meander scar that remained in the E 1/2 sec. 30, T48N, R16W.

Simple paleodischarge calculations based on meander wavelengths (Dury, 1965) yield bank-full discharges of 1,100-1,200 m^3/sec, or 45 times mean annual discharge of the modern Tahquamenon River. Though large by modern standards, these figures are comparable to glacial meltwater flows from outwash features described by others (Clague, 1975; Maizels, 1982; Blewett, 1990).

Phases 4 and 5

Eventually, ice withdrew to a position several kilometers north of the Lower Kingston margin, initiating eastward meltwater drainage across a broad terrace heading at 230 m (Fig. 5-4). Further retreat initiated two episodes of incision (225 and 215 m) into the 230 m channel (Fig. 5-5). These surfaces are best observed south of Beaver Lake (secs. 17-20, T48N, R16W).

Phase 6

The glacial border finally retreated to a position just south of Grand Portal Point (Fig. 5-6), forming the last barrier separating lakes in the western and eastern sections of the Lake Superior basin (Drexler, 1981; Fig. 4). Further ice withdrawal allowed western lakes to spill eastward into an early version of Lake Minong, cutting the Chapel and Little Chapel gorges. Continued ice-marginal retreat allowed Lake Minong to expand north and westward into the remaining parts of the basin by 9,500 B.P., to eventually form the first post-glacial lake in the Superior basin (Farrand and Drexler, 1985).

DISCUSSION AND CONCLUSIONS

Due to variations in glacier processes, surficial sediments and landform assemblages differ markedly between western and eastern sections of PRNL. The Melstrand esker and small, incised, subglacial channels west of Miners River (secs. 21, 28, and 29, T47N, R18W) are indicative of well developed subglacial or englacial drainage systems commonly associated with warm-based or temperate glaciers in which surface meltwater can penetrate to the glacier bed (Mooers, 1990). In contrast, large, coalescing outwash aprons

(Upper Kingston apron, Section 35 Hill) and hummocky stagnation topography often form from large accumulations of superglacial drift that may be associated with colder glaciers with frozen margins (Mickelson and others, 1983; Mooers, 1990).

The presence of eskers south of the park (Nawakwa, Casey Creek, Casey Lake, and Kingston eskers; Blewett, 1984), may indicate a change to warm-based conditions during final deglaciation, typical of retreating glaciers (Clayton and Moran, 1974). Thus, differences among landforms and surficial sediment characteristics in PRNL and vicinity likely represent contrasting spatial and temporal variations in glacier thermal regime.

Drexler's contention that the Munising moraine is simply higher bedrock, thinly mantled with drift, is based on the presence of bedrock outcrops "near the crests of moraine segments (Drexler et al., 1983. p. 311)." Outcrops mapped by Drexler (1983, p. 312-313), however, are located either west of Beaver Lake or along the headlands south of Grand Marais, regions encompassing only a small part of the Munising moraine and long recognized as containing thin drift. Karrow states (1983, p. 263):

"Leverett's Munising and Newberry moraines appear to form a coherent set of features...Although Drexler recently downgraded the importance of Leverett's moraines, they appear to mark at least the trend of the ice front..."

Later (1987, p. 118) he writes:

"Drexler and others (1983) have disputed Leverett's (1929) identification of moraines in eastern upper Michigan west of Whitefish Point, claiming that they represent bedrock highs rather than true ice-marginal accumulations. The writer agrees that, for example, the Niagara Escarpment bedrock high does occur under some of the mapped moraines farther east, but even so, some morainic topography is present. A prominent bedrock scarp would naturally tend to cause ice-marginal stability along its trend. Only detailed remapping and gathering of available subsurface information on bedrock topography will resolve the question."

Based on the most detailed and comprehensive bedrock data available, Blewett and Rieck (1987) showed that drift thickness within areas mapped as moraine south and east of Beaver Lake likely exceeds 20 m. Combined with evidence from this report, these data show unequivocally that the Munising moraine marks an important and conspicuous series of ice-marginal positions, not a bedrock high thinly mantled with drift.

Contradictions between the revised age of the Munising moraine (Drexler et al., 1983) and its apparent gradation to much older Algonquin lake levels (Hough, 1958; Futyma, 1981) can be easily resolved if the Munising moraine is viewed as a compound feature. If so, the ice margin may have paused here 11,000 B.P. along the trend of the underlying Cambrian-Ordovician bedrock escarpment, building large outwash aprons graded to Algonquin water levels.

After retreating northward during the Gribben Interstadial, the ice margin then readvanced to the same general position, building a second marginal accumulation atop the first that was graded to low lake levels in the Michigan basin. Supporting evidence includes the Long Lake channel, which is apparently graded to a low water level in the Michigan basin, whereas landforms farther east appear graded to lake levels consistent with Algonquin water planes. Verification of this hypothesis requires data not now available.

Nevertheless, most glacial terrain within PRNL formed within a 300-500 year period commencing approximately 9,800 B.P. as a retreating ice margin confined meltwater streams against the Munising moraine to the south. Spatial and temporal differences in glacier dynamics likely produced the significant variations in surficial sediment characteristics and landform assemblages present within the park.

Large coalescing outwash aprons, kame terraces, and incised channels collectively record long intervals of quasi-stable ice-marginal conditions favoring thick outwash deposition, punctuated by comparatively brief transitional periods of rapid incision due to ice-marginal retreat from highlands south of Grand Marais. The Munising moraine represents a significant ice-marginal accumulation containing abundant ice-contact and proglacial stratified drift formed along a stagnant ice margin.

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